

CALIBRATING METHOD AND APPARATUS IN A TELECOMMUNICATION SYSTEM

TECHNICAL FIELD OF THE INVENTION

This invention relates to a calibration method and
5 arrangements and, in particular, calibration in an antenna
receiver included in a radio base station.

DESCRIPTION OF RELATED ART

Radio systems are in use throughout the world transmitting
telecommunications signals to radio receivers. In order to
10 meet the capacity demand within the available frequency band
allocation, radio operators divide a geographic area to be
covered by cells. At the center of each cell there is a
transceiver in a base station, which broadcasts radio
signals. The available operating frequencies are distributed
15 among the cells such that adjacent cells do not reuse the
same group of operating frequencies, in order that co-
channel interference is maintained at a tolerable level.

When a new radio system is initially deployed, operators are
often interested in maximizing the downlink range (base
20 station broadcast range). Any increase in range means that
fewer cells are required to cover a given geographic area,
hence reducing the number of base stations and associated
infrastructure costs. The antenna used at the radio base
station site can potentially make significant improvements
25 to the range and capacity of a radio system. Associated with
this requirement is the need to ensure that received signals
are processed with the least amount of distortion and loss.
At the masthead of the base station, signals from the
antenna pass through a filter and a duplexer and then
30 through cabling to receive electronics, where the signal is
amplified. Some antennas have associated receive amplifiers

which boost the signal prior to further signal degradation on passing through the cabling as the signals are transmitted to the base station electronics unit. At this point the received signal is ideally above a particular level.

In the cases where receive amplifiers are situated adjacent to the antennas, the amount of gain needs to be accurately determined. The signal strength received is normally measured by measurement at the time of installation in order to guarantee a receive level in the base station arrangement. There is a gain variation at the amplifiers and there is a loss through the duplexer. Further losses arise due to the cabling, with variations in temperature and also variations which occur from one batch to another in respect of equipment employed. Losses due to frequency variations are, however, negligible in relation to variation in cable length which can be large considerable. The variation in is dependent on arises from the position of an antenna on a mast, which can typically be 10 meters to 100 meters in height. Base station control electronics are normally situated at the bottom of the mast since that is normally convenient, but it may be located 20 meters away, for instance, by a convenient power source or for protection against vandals. Such losses need not be considered in relation to the transmit path since there is typically a feedback link which keeps the output constant with power detectors, couplings at the antenna and they then feed back a signal digitally down to the base station.

For a specific installation the variables of temperature, frequency and length can be taken into account by specific circuitry, but operational variations for the components at the antenna cannot be taken into account, since these variables are outside the dynamic range of the base station.

These have to be monitored on an individual basis, and are taken into account on installation. In practice a variable gain block is provided which allows the signal received to be adjusted to a certain level which is consistent with the amount of loss associated with the system. In some systems a noise source is placed up the masthead and the system is characterized with reference to this source. Furthermore, any method using/incorporating a reference level at the masthead is susceptible to further problems arising from extra equipment, which consumes electricity, generates heat and will also reduce the reliability potential since it exists as an extra component. The signal source needs to be very stable over a wide temperature range (minus 40 DEG to plus 80 DEG C), tends to be expensive and is typically only used once.

The power loss caused by the cabling up to the masthead can accordingly be determined and the loss due to the cabling can be compensated by appropriate adjustment of the gain of the receive amplifier.

- 20 It is previously known, see for example EP0793 292, A1, that a noise meter monitors a noise signal received from a front-end receiving amplifier in a given channel and compares this with noise from a reference amplifier. A spectrum analyser is used to measure the noise figure of the amplifier.
- 25 Furthermore in WO 95/19574 it is previously known that switching means is used to disconnect the antenna from the amplifier section while connecting a low-loss transmission line to the antenna to measure the condition of the antenna.

SUMMARY OF THE INVENTION

In a receiver and a method for calibrating a receiver, which comprises one or more amplifiers in a chain, the gain of the receiver is variable in time and with temperature.

5 It is of importance to know the gain of the receiver, for the whole system to work properly of which the receiver is only a small part.

It is an object of the present invention to provide a less expensive and more accurate apparatus for and method of
10 performing calibration of the amplifiers preferably in an antenna installation.

Briefly, these and other objects of the present invention are accomplished by using a calibrating signal, preferable the noise generated by one or more amplifiers in the
15 receiver as a reference source.

An advantage of the present invention is that an external reference source when calibrating the gain of a receiver can be avoided.

Another advantage of the present invention is possibility to
20 monitor the gain of the receiver during operation.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings and claims.

DESCRIPTION OF THE DRAWINGS

For a better understanding, reference is made to the following drawings and preferred embodiments of the invention.

- 5 FIG. 1 illustrates an antenna receiver with one amplifier and a calibration arrangement according to the first embodiment of the invention.

- 10 FIG. 2 illustrates an antenna receiver with amplifiers in a chain and a calibration arrangement according to the first embodiment of the invention.

FIG. 3 illustrates an antenna receiver, during normal operation, with amplifiers in a chain and a calibration arrangement according to the second embodiment of the invention.

- 15 FIG. 4 illustrates an antenna receiver, during calibration, with amplifiers in a chain and a calibration arrangement according to the second embodiment of the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

- 20 Fig. 1 and 2 represent a first embodiment 1 of the present invention, an antenna receiver calibrating arrangement, while Fig. 3 and 4 represent a second embodiment 2 of the present invention.

- 25 In Fig. 1-4 the antenna receiver comprises an antenna with one or more amplifiers located in a chain, wherein the noise $N_a + N_i$ produced by the amplifier/amplifiers 100/200 can be a reference value during estimation of the gain G of the

receiver embodiments 1 or 2. Signal loss due to aging of the components and ambient variations as e.g., temperature can thereby be compensated.

In the first embodiment 1 of present invention, Fig. 1, of the receiver one amplifier 100 is connected between a receiving antenna 300 and an analog-digital-converter 400. With a switch 10 the input to the single amplifier 100 is connected to a reference potential, preferably through a resistance 20 to ground (of approx. 50 Ohm). In Fig. 2, the first embodiment 1 is illustrated where more than one amplifier is used in a chain 100 plus 200. The amplifier 100 closest to the receiving antenna 300 is connected to a reference potential, as in Fig. 1, preferably through a resistance 20 to ground (of approx. 50 Ohm). The resistance 20 in Fig. 1 and 2 (of approx. 50 Ohm) is provided to prevent the amplifier/amplifiers from oscillating.

With the switch 10 connected to the reference potential via the resistance 20, Alt. 2 in Fig. 1 or 2, no input signal S_i or input noise N_i , at the antenna 300 is input to the amplifier/amplifiers 100/200. In that case there is an inherent noise N_a from the amplifier/amplifiers 100/200 and an input noise N_i produced by the resistance 20 instead of the antenna, in Alt. 1, that are the cause of a total output signal S_{tot} ($=S_o+N_o=S_i \cdot G+N_i \cdot G+N_a$) before and after the ADC, depending on where the total output signal S_{tot} is measured. Amplifiers generate a noise N_a even if there is no input signal S_i ($=0$); i.e. the level of noise present is always above zero.

It is not necessary a resistance that is placed between the amplifier/amplifiers and ground, it may e.g., be a filter or impedance.

The noise figure F is a method of specifying the noise performance of a circuit or a device. The definition of the noise figure F of a circuit is

$$F = \frac{S_i/N_i}{S_o/N_o};$$

5 where

S_i = input signal;

N_i = input noise signal;

S_o = output signal;

N_o = output noise signal.

10 The noise figure F is usually expressed in decibel and F can be interpreted as a direct signal-to-noise ratio degradation. Noise output N_o consists of the input noise N_i which is the noise transmitted from the source resistance and the inherent noise N_a which is the noise from the circuit
 15 itself. The noise N_i is mostly arising from random electron motion, which is called thermal noise. It is directly proportional to the bandwidth B of the noise, the Boltzman constant k , and the temperature T . The amount of thermal noise to be found in a bandlimited system is (or the noise
 20 power is)

$$k \cdot T \cdot B \text{ (W)};$$

where

k =Boltzman constant ($1.4 \cdot 10^{-23}$ J/K);

T =absolute temperature (K, Kelvin) of thermal noise;

B =bandwidth of the noise (Hz).

- 5 In a simple circuit with an input signal S_i with input noise N_i coupled to an amplifier with a gain G and an inherent noise N_a and output signal S_o ($=S_i \cdot G$) the noise figure F is equal to

$$F = \frac{S_i/N_i}{S_o/N_o} = \frac{S_i/N_i}{S_i \cdot G / (N_i \cdot G + N_a)} = 1 + \frac{N_a}{N_i \cdot G};$$

- 10 $\Rightarrow N_a = N_i \cdot G (F - 1)$.

For a system of amplifiers connected in a chain as in the invention a general relationship of the noise figures would be

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 \cdot G_2} + \dots + \frac{F_n - 1}{G_1 \cdot G_2 \cdots G_{n-1}};$$

- 15 where F is the total noise figure of the whole chain of amplifiers and F_1, \dots, F_n is the noise figure of the resp. amplifier and G_1, \dots, G_n is the gain of resp. amplifier.

In the first embodiment 1 of present invention, Alt. 1, Fig 2 when not in calibrating mode and when the actual input signal is S_i the total output signal S_{tot} is equal to

$$S_{tot} = S_i \cdot G_1 \cdots G_n + N_i \cdot G_1 \cdots G_n + N_{a1} \cdot G_2 \cdots G_n + N_{a2} \cdot G_3 \cdots G_n + \cdots +$$

5 $+ N_{a(n-1)} \cdot G_n + N_{an} .$

In the first embodiment 1 of present invention, Alt. 2, according to Fig. 2, there is no input signal S_i to the amplifiers since the switch 10 is connected to the reference potential 20. The noise power N_i is then input from the resistance 20 and potential reference, and the amplifiers produce an inherent noise N_a , total output signal S_{tot} is then equal to

$$S_{tot} = N_i \cdot G_1 \cdots G_n + N_{a1} \cdot G_2 \cdots G_n + N_{a2} \cdot G_3 \cdots G_n + \cdots + N_{a(n-1)} \cdot G_n + N_{an} ;$$

$$\Rightarrow S_{tot} = N_i \cdot G + N_a ; \text{ when}$$

$$15 \quad N_a = (N_{a1} \cdot \frac{1}{G_1} + N_{a2} \cdot \frac{1}{G_1 \cdot G_2} + \cdots + N_{an} \cdot \frac{1}{G_1 \cdots G_n}) \cdot G ; \text{ and}$$

$$G = G_1 \cdots G_n ;$$

where N_{a1}, \dots, N_{an} is the inherent noise N_a of the resp. amplifier and G_{a1}, \dots, G_{an} is the gain G of resp. amplifier. The incoming noise signal N_i is in this case the noise produced in the resistance 20 instead of the noise signal N_i coming from the antenna 300.

20

These equations are also valid when only one amplifier as in Fig. 1 is used, but then is total output signal S_{tot} equal to

$$S_{tot} = N_i \cdot G_1 + N_{a1} ;$$

$$\Rightarrow S_{tot} = N_i \cdot G + N_a ; \text{ when}$$

$$5 \quad N_a = N_{a1} ; \text{ and}$$

$$G = G_1 .$$

With the assumption that the input noise N_i is mostly arising from random electron motion, thermal noise, and using the earlier derived equation for inherent noise $N_a (=N_i \cdot G(F-1))$ for a simple circuit, and the expression for the amount of thermal noise found in a bandlimited system $(=k \cdot T \cdot B)$, an equation can be derived for the total output signal S_{tot} , in Alt. 2, for one amplifier in embodiment 1, Fig. 1

$$S_{tot} = N_i \cdot G + N_a = N_i \cdot G + N_i \cdot G \cdot (F-1) = N_i \cdot G \cdot F = k \cdot T \cdot B \cdot F \cdot G$$

$$15 \quad \Rightarrow G = \frac{S_{tot}}{k \cdot T \cdot B \cdot F} .$$

The total output signal S_{tot} in the first and second embodiment 1 and 2 from the analog-digital-converter 400 is measured with a noise meter 600 either after the analog-digital-converter 400 or before, right after the last amplifier 200, and by means of the input noise power $N_i (=k \cdot T \cdot B)$, a measured temperature T of the receiver, the bandwidth B of the noise power, the Boltzman constant k , and

a known noise figure F of the amplifier the gain G of the receiver can be estimated from the equation

$$G = \frac{S_{\text{tot}}}{k \cdot T \cdot B \cdot F}.$$

In this connection, Alt. 2, for both the embodiment 1 and 2
 5 the assumption is used that variation in noise figure F over ambient temperature T is smaller than the variation in gain G .

A switch 10 as used in the first embodiment 1 of the present invention, Fig. 1 and 2, produces an insertion loss which
 10 increases the noise figure F , and which decreases the sensitivity of the receiver during normal operation, Alt. 1.

A second embodiment 2, of the present invention, according to Fig. 3 and 4 which does not increase the noise figure F during normal operation is suggested.

15 In the second embodiment 2 of the receiver, Fig. 3 and 4, which does not increase the noise figure F during normal operation, no switch 10 as in Fig. 1 and 2 is used. Instead, the amplifier 100 closest to the receiving antenna 300, in Fig. 4, is disconnected 30 by that no power, DC supply 500,
 20 is supplied to the amplifier 100. The amplifier 100 itself works as a switch, which means that this amplifier 100 is working as an interruption with no gain G_1 and disconnects the other amplifiers 200 from the signal source S_i . The remaining amplifiers 200 are producing a noise power $N_{a2} \cdots N_{an}$
 25 as in the first solution. The amplifier 100 working as a switch is not producing an inherent noise N_{a1} , and has no gain G_1 , but is producing the input noise N_i corresponding to the input noise produced by the reference potential 20 in embodiment 1, Alt. 2. In Alt. 1 for both embodiment 1 and 2

the input noise N_i is produced by the "input termination", the antenna. As the "switch amplifier" has no gain G_1 and is not producing an inherent noise N_{a1} in Alt. 2, embodiment 2, Fig. 3 and 4, a single amplifier 100 as is illustrated in Fig. 1 for the first embodiment 1 can not be used in Alt. 2 when estimating the gain G of the receiver. Conclusion is for embodiment 2 that at least more than one amplifier in a chain is needed for the invention to work in calibrating mode Alt. 2.

- 10 There is no need to connect a reference potential 20 (a resistance to ground of approx. 50 Ohm) to prevent the amplifiers from oscillating. The DC power supplies of the various amplifiers 100-200 are separated, or as shown in Fig. 3 and 4, one DC supply 500 to all amplifiers, but
 15 amplifier 100 is disconnected from the DC supply by a switch 30.

In second embodiment 2 of present invention, Alt. 1, when not in calibrating mode, the total output signal S_{tot} is equal to

$$20 \quad S_{tot} = S_i \cdot G_1 \cdots G_n + N_i \cdot G_1 \cdots G_n + N_{a1} \cdot G_2 \cdots G_n + N_{a2} \cdot G_3 \cdots G_n + \\ + \cdots + N_{a(n-1)} \cdot G_n + N_{an} .$$

- In second embodiment 2 of present invention, Alt. 2, according to Fig. 4, in the case when there is no input signal S_i to the amplifiers, the "switch amplifier" 100 is
 25 working as an interruption, the noise power N_i is input from the "switch amplifier" 100, and the amplifiers 200 produce an inherent noise N_a .

The "switch amplifier" 100 produce no inherent noise N_{a1} , total output signal S_{tot} is then equal to

$$S_{tot} = N_i \cdot G_2 \cdots G_n + N_{a2} \cdot G_3 \cdots G_n + \cdots + N_{a(n-1)} \cdot G_n + N_{an} ;$$

$$\Rightarrow S_{tot} = N_i \cdot G + N_a ; \text{ when}$$

$$5 \quad N_a = (N_{a2} \cdot \frac{1}{G_2} + N_{a3} \cdot \frac{1}{G_2 \cdot G_3} + \cdots + N_{a(n-1)} \cdot \frac{1}{G_2 \cdots G_{(n-1)}} + N_{an} \cdot \frac{1}{G_2 \cdots G_n}) \cdot G ; \text{ and}$$

$$G = G_2 \cdots G_n .$$

where N_{a2}, \dots, N_{an} is the inherent noise N_a of the resp. amplifier and G_{a2}, \dots, G_{an} is the gain G of resp. amplifier. Instead of the incoming noise signal N_i from the antenna is
 10 an input noise N_i produced by the switch amplifier 100 in Alt. 2.

From the equation

$$G = \frac{S_{tot}}{k \cdot T \cdot B \cdot F} ;$$

derived from embodiment 1, Alt. 2, with one amplifier, it is
 15 possible to estimate the gain G for more than one amplifier in a chain for embodiment 1 and 2 Alt. 2. With a noise meter 600 is measured the total output signal S_{tot} in the first and second embodiment 1 and 2. Input to the equation is this measured total output signal S_{tot} and the measured
 20 temperature T of the receiver, the bandwidth B of the noise, and the Boltzman constant k . From a known noise figure for each amplifier in the receiver is an approximation made of

noise figure F for the whole receiver. By means of all this data is then the gain G ($=G_1 \cdots G_n$) for the whole receiver estimated (in embodiment 2 is the gain G equal to $G_{a2} \cdots G_{an}$, described above).

5 In the first embodiment 1, Fig. 1 and 2, there is insertion loss due to a separate switch 10 which also affects the noise figure F during normal operation. In the second embodiment 2, Fig. 3 or 4, the amplifier closest to the receiving antenna is the switch 100 in itself. However, in
10 the second embodiment 2, where at least one amplifier is disconnected (at least more than one amplifier in a chain is needed for the invention to work in calibrating mode Alt. 2), working as an interruption, the gain G of this amplifier is not included in the calibration. The accuracy of the gain
15 G estimation of the total receiver is thereby reduced with the gain inaccuracy of the switched off amplifier. The noise figure F of the receiver is also affected in embodiment 2, Alt. 2, it is increased.

It is preferable that the gain of the switched off amplifier stage 100 is as low as possible. This is to keep the
20 accuracy of the gain G measurements on a high level.

With a high gain amplifier 100 disconnected in the second embodiment 2 according to Fig. 3 or 4 this high level accuracy is not achieved. This is also an answer to why the
25 accuracy is decreased if only two amplifiers and not a chain of many amplifiers 100 plus 200 are used in a receiver in the second embodiment 2. If two amplifiers existing and one is disconnected it will affect the normal operation more than if one amplifier out of a chain of many amplifiers is
30 disconnected.

A solution to this problem in the second embodiment 2 in a receiver is to provide a low gain amplifier in a chain of

amplifiers closest to the antenna and to let this low gain amplifier be the disconnected amplifier.

For a receiver it is preferable, for best operation of the receiver, to provide a high gain amplifier next to the antenna. A high gain amplifier is often delivered in a packaged chip consisting of more than one amplifier stage. The amplifiers stages in the chip in series produce a high gain. There is normally only one power supply per chip, the same to all of the amplifiers stages. If you disconnect the whole chip to use it as a switch, as it is impossible to separate the series coupled amplifiers in one chip with only one power supply, it results in a high gain amplification being disconnected (at least more than one amplifier in a chain is needed for the invention to work in calibrating mode Alt. 2, this means that beside the high gain amplifier in one chip another amplifier is needed). A solution to a high gain amplifier in chip of series coupled lower gain amplifier stages would be to get a chip in the future in which the first amplifier stage has its own power supply pin. If that chip existed no power supply would be fed to the first amplifier in the series coupled amplifiers on the chip, and the chip of high gain would be disconnected from the antenna, the input signal, and the second embodiment 2 of the invention is reached, but with improved accuracy of gain estimation.

In the future for any reason it may be of favor to provide the reference potential 20 in the first embodiment 1, or the switch amplifier 100 in the second embodiment 2 somewhere in the chain of amplifiers and not closest to the antenna 300 as described previously.

Allowing a short disconnect time of the input signal from the amplifier/amplifiers the calibration can be carried out during operation.

An antenna and/or amplifiers can carry signals of different carrier frequencies, it is advised to calibrate all receiver chains making use of that disconnected antenna at the same time. This can be done by means of a divider whose input is
5 connected to the last amplifier stage and whose output are connected to the different carrier frequency amplifiers.

In accordance with another aspect of the invention, there is provided a method for calibrating the receiver, wherein the receiver comprises one or more amplifiers in a chain. The
10 amplifier/amplifiers 100/200 are generating a noise signal N_a+N_i at the same time as an input signal S_i+N_i is disconnected Alt. 2 to the receiver. The noise signal is used as a calibrating signal for estimating a corresponding gain (G) of the receiver, by measuring (600) at the output
15 of the receiver the amount of noise (S_{tot}) of the amplifier/amplifiers in the chain. The gain (G) is adjusted in accordance to the calibrating signal.